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(71)Applicant : NIPPON TELEGR & TELEPH CORP <NTT>
(72)Inventor : SHOJI TETSUSHI
YAMADA KOJI
MORITA HIROBUMI
NOTOMI MASAYA
ARAYA AKIHIKO
YOKOHAMA ITARU

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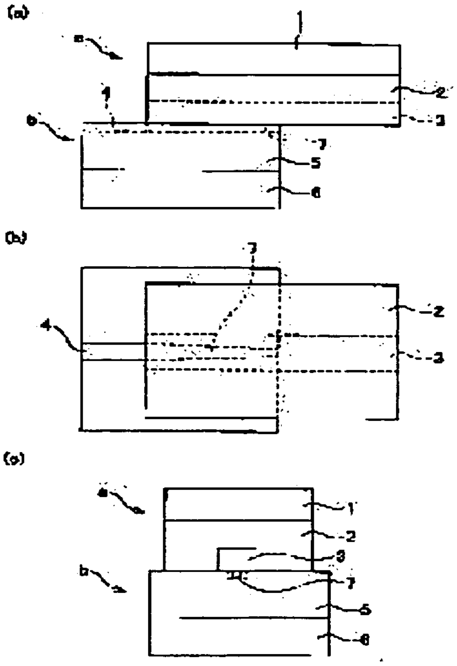
(54) STRUCTURE FOR CONNECTING OPTICAL WAVEGUIDE



(57)Abstract:

PROBLEM TO BE SOLVED: To provide an optical waveguide connection structure that enables reduction in connection loss between optical waveguides of a different spot size in the waveguide mode, as well as reduction in reflection attenuation, that requires no high accuracy in a connecting device or operation, and that is easily manufactured by manufacturing process technology of an integrated circuit.

SOLUTION: The optical waveguide connecting structure is for optically connecting, a first optical waveguide (a) having a first core 3 guiding/ transmitting light and a clad 2, whose refractive index is smaller than that of the first core, with a second optical waveguide (b), having a second core 4 that has a refractive index larger than that of the first core of the first optical waveguide. In the second core of the second optical waveguide, a tapered part 7 is formed, of which the dimension in the width direction diminishes toward the end of the second waveguide, while the cross sectional height is maintained in the longitudinal direction, and the first core of the first optical waveguide and the tapered part in the second core of the second optical waveguide are arranged so as to be optically closed to each other in a state with them being contacted or parallel with each other longitudinally.

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(71)出願人　000004226
日本電信電話株式会社
東京都千代田区大手町二丁目３番１号

(72)発明者　荘司　哲史
東京都千代田区大手町二丁目３番１号　日本電信電話株式会社内

(72)発明者　山田　浩治
東京都千代田区大手町二丁目３番１号　日本電信電話株式会社内

(74)代理人　100064414
弁理士　磯野　道造

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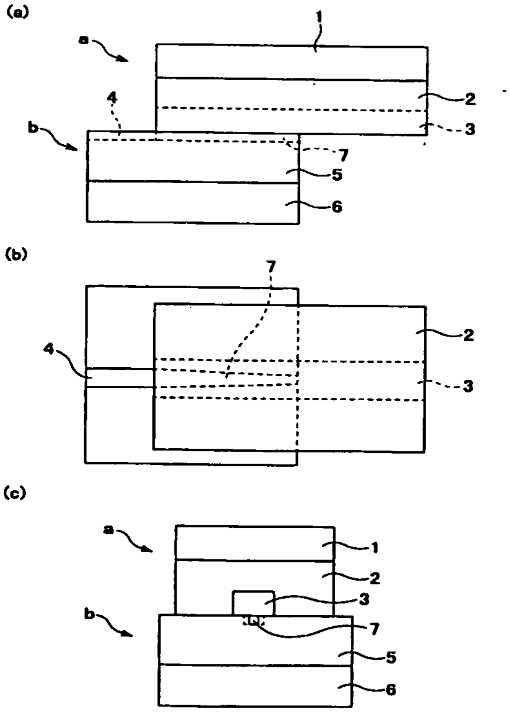
(54)【発明の名称】　光導波路接続構造

(57)【要約】

【課題】光導波路の導波モードのスポットサイズが異なる光導波路同士の接続損失や、反射減衰量を小さくすることが可能で、接続のための装置や作業に高い精度を必要とすることなく、しかも集積回路製造プロセス技術により容易に製造可能な光導波路接続構造を提供することを課題とする。

【解決手段】　光を導波伝搬する第１コア３、この第１コアよりも屈折率が小さいクラッド２を有する第１光導波路ａと、この第1光導波路の第１コアの屈折率よりも屈折率が大きい第２コア４を有する第２光導波路ｂとを光学的に接続する光導波路接続構造において、前記第２光導波路の第２コアは、長手方向の断面高さを維持した状態で、その幅方向の寸法をその第２導波路の端部に向かって小さくなるテーパ部７を形成し、前記第1光導波路の第１コアと、前記第２光導波路の第２コアにおける前記テーパ部とが長手方向に接触または平行な状態で光学的に近接するように配置されている光導波路接続構造とした。



【特許請求の範囲】

【請求項１】　光を導波伝搬する第１コアおよびこの第１コアよりも屈折率が小さいクラッドを有する第１光導波路と、この第1光導波路の第１コアの屈折率よりも屈折率が大きい第２コアを有する第２光導波路とを光学的に接続する光導波路接続構造において、

前記第２光導波路の第２コアは、長手方向の断面高さを維持した状態で、その幅方向の寸法をその第２導波路の端部に向かって小さくなるテーパ部を形成し、前記第1光導波路の第１コアと、前記第２光導波路の第２コアにおける前記テーパ部とが長手方向に接触または平行な状態で光学的に近接するように配置されていることを特徴とする光導波路接続構造。

【請求項２】前記第１光導波路と前記第２光導波路とが同一の基板に形成され、かつ、前記基板に形成されるクラッドが連続した同一素材よりなることを特徴とする請求項１に記載の光導波路接続構造。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、光を導波伝搬する光導波路同士を接続する光導波路接続構造に係り、特に、屈折率の異なる光導波路を互いに接続する場合に適した光導波路接続構造に関するものである。

【０００２】

【従来の技術】一般に、平面光導波路を配線部材として、発光素子、受光素子、光変調器等の光回路素子を集積して形成される光集積回路は、高度な光信号処理が可能であり、量産性、安定性、コスト性等の観点から、光通信における主要な部品となりつつある。この光集積回路に用いられる光回路素子の多くは、内部に屈折率による光閉じこめ構造にもとづく導波路構造を持ち、配線部材である光導波路との高効率な結合が求められている。

【０００３】一方、光集積回路内の配線部材である平面導波路においても、従来の石英系の素材から、シリコンを素材に用いる構造が研究されており、既存の石英系あるいはポリマー導波路等との接続が求められている。

【０００４】ところが、シリコンをはじめとする半導体の屈折率は、光通信にもっぱら用いられる近赤外域において石英系素材やポリマー系素材のそれと比較して約２倍から３倍程度大きな値を持っている。そのため、シリコン材料よりなるシングルモード条件を満たすコアの断面は、例えば、クラッドの材料が石英で、コア断面が厚さ０．２μmの矩形である場合、幅が０．４μm程度あるいはそれ以下となり単に導波路端面を突きあわせるだけでは、高効率な結合を実現することが困難である。したがって、結合される導波路コアは、その先端部を厚み方向にテーパ状に加工することによりモードフィールド径の拡大を図り、高効率な結合を実現している。この従来技術を図４により示す。図４（ａ）、（ｂ）は従来の光導波路接続構造の側面状態を示す概略図である。

【０００５】図４（ａ）、（ｂ）に示すように、導波路コア先端部１００は、平面基板１２６の上に、アンダークラッド１２５、オーバークラッド１２３に挟み込まれる形で、周囲より屈折率の高いコア部１２４となめらかに断面積の変化するテーパ部１２９が形成されている。なお、導波路コア先端部１００に接続される光導波路（光ファイバ等）１０１は、石英系素材よりなるクラッド１２７と、このクラッド１２７の内側に形成された石英系素材よりなるコア部１２８とを備えており、コア部１２８はクラッド１２７よりわずかに大きな屈折率を有している。

【０００６】そのため、光導波路であるコア部１２４の左端から入射した光は、断面積の小さいテーパ部１２９の右端ではモードフィールド径が拡大され、石英系素材よりなるコア部１２８に低損失で結合される。この時の接続損失は、たとえば「ＯＮＵ（光ネットワークユニット）の光技術」（光学　第２４巻　第５号（１９９５年５月））では、計算値で０．５ｄＢ程度、実験値で０．７５ｄＢ程度の数値が示されている。

【０００７】

【発明が解決しようとする課題】しかし、前記した従来の光導波路接続構造ではテーパ部分の形状・特に先端部での断面形状は高精度で加工することが要求されることになった。また、前記の結合構造では接続する二つの導波路端面のどちらも高い精度での研磨が必要であり、研磨作業が大変であった。さらに、前記の光導波路接続構造では、屈折率の低い方のコア径における１０分の１程度の精度で位置決めを行う必要があり、位置決め操作が大変であった。

【０００８】また、前記の光導波路接続構造では、屈折率の高いコアと、屈折率の低いコアの中心軸を同一平面上とする事が必要であるため、同一の平面基板上に二つの導波路を複合して形成するためには、高さ方向の加工を伴う複雑な手順が要求されることになった。さらに、前記の光導波路接続構造では、両端面間での反射損失を低減させるため、端面に無反射コーティング等の加工を行う必要があった。

【０００９】本発明は、前記の問題点に鑑み創案されたものであり、その目的は、光導波路の導波モードのスポットサイズが異なる光導波路同士の接続損失や、反射減衰量を小さくすることが可能で、接続のための装置や作業に高い精度を必要とすることなく、しかも集積回路製造プロセス技術により容易に製造可能な光導波路接続構造を提供することにある。

【００１０】

【課題を解決するための手段】前記課題を解決するため、本発明ではつぎのように構成した。すなわち、光を導波伝搬する第１コアおよびこの第１コアよりも屈折率が小さいクラッドを有する第１光導波路と、この第1光導波路の第１コアの屈折率よりも屈折率が大きい第２コ

アを有する第２光導波路とを光学的に接続する光導波路接続構造において、前記第２光導波路の第２コアは、長手方向の断面高さを維持した状態で、その幅方向の寸法をその第２光導波路の端部に向かって小さくなるテーパ部を形成し、前記第1光導波路の第１コアと、前記第２導波路の第２コアにおける前記テーパ部とが長手方向に接触または平行な状態で光学的に近接するように配置されている光導波路接続構造とした。

【００１１】このように構成されることにより、この第１コアおよび第２コアの接続部分における導波モードが光を入力する側から光を出力する側へ行くに従い、光を入力する側の光導波路のコアを通過する光パワーが、出力する側の光導波路のコアを通過する光パワーより大きい状態から、光を出力する側の光導波路のコアを通過する光パワーが、入力する側の光導波路のコアを通過する光パワーより大きい状態へ徐々に変化するようになる。

【００１２】また、前記した光導波路接続構造において、前記第１光導波路と前記第２光導波路とが同一の基板に形成され、かつ、前記基板に形成されるクラッドが連続した同一素材よりなるように構成した光導波路接続構造とした。このように構成することにより、低損失で接続できるという利点がある。また、テーパ部の高さ方向の加工を必要としない利点がある。

【００１３】

【発明の実施の形態】以下、本発明にかかる光導波路接続構造を、図面を参照して詳細に説明する。図１は本発明にかかる第一の実施の形態である。図１（ａ）は、光導波路接続構造の正面状態を示す模式図、（ｂ）は（ａ）の平面状態を示す模式図、（ｃ）は（ａ）の右側面状態を示す模式図である。

【００１４】図１（ａ），（ｂ），（ｃ）に示すように、第１光導波路ａは、平面基板１と、この平面基板１の一方面に形成される石英系素材よりなるアンダークラッド２と、このアンダークラッド２の一方面の中央に沿って形成される石英系素材よりなる光導波路コア３（第１コア）とを備えている。

【００１５】また、第２光導波路ｂは、平面基板６と、この平面基板６の一方面に形成される石英系素材よりなるアンダークラッド５と、このアンダークラッド５の一方面で中央に沿って形成されるシリコンよりなる光導波路コア４（第２コア）と、この光導波路コア４の端部に、その光導波路コア４の断面高さ（厚さ）を維持した状態で幅寸法を先端に向かうに従って細くなるように連続的に変化して形成されたテーパ部７とを備えている。

【００１６】そして、第２光導波路ｂのテーパ部７は、第１光導波路ａの光導波路コア３と長手方向に接触または平行な状態で光学的に近接するように配置された状態で配置されている。なお、ここでは、第１光導波路ａと、第２光導波路ｂとを光硬化樹脂などの接続部材を介して結合させた状態としている。テーパ部７と光導波路コア３との位置関係は、軸線同士が一致していることが望ましいが、光導波路コア３の幅内で平行にズレる状態や、あるいは光導波路コア３の幅内にテーパ部７が収まる程度の状態であれば良く、厳密な整合性を必要とするものではない。また、平行な状態で光学的に近接するとは、伝搬する光が許容範囲の損失内で適切に一方から他方に伝わることができる状態である。

【００１７】アンダークラッド２および光導波路コア３、アンダークラッド５の屈折率は、添加不純物および使用波長帯域により異なるが近赤外光の領域においては、いずれもおおむね１．４から１．５程度である。一方、光導波路コア４の屈折率は、おおむね３．４程度である。光導波路コア４の厚さは０．２μｍ程度、幅は０．４μｍ程度であり、光導波路コア３の厚さと幅はいずれも２１μｍ～１０μｍ程度である。

【００１８】また、テーパ部７は、その幅が左端（光導波路コア４側）においては光導波路コア４の幅から右端（先端）に向かうにしたがって０．１μｍあるいはそれ以下となるように形成されている。このテーパ部７の長さは数十μｍ程度から１ｍｍ程度に形成されている。このテーパ部７の幅および長さは、接続する側の光導波路コアに対して位置決めなどを行う場合に操作が容易となる寸法に形成されていれば、特に限定されるものではない。なお、前記した各構成の寸法は、ここで挙げた寸法以外であっても構わない。

【００１９】つぎに、光導波路接続構造における光の伝搬状態を説明する。光導波路コア４の左端面から入射した光は、光導波路コア４を伝搬しテーパ部７の左端位置に到達する。光導波路コア３の左端において光導波路コア４のクラッドの役割をする空気と光導波路コア３の屈折率の違いにより、一部の光が反射するが、空気と光導波路コア３との屈折率の違いは、光導波路コア４と空気あるいはテーパ部７と光導波路コア３の屈折率の違いにくらべると相対的に小さいので、この反射光強度は弱い。

【００２０】光がテーパ部７を図１における右方向に伝搬するにつれて、コア幅が徐々に狭まり光の閉じこめが弱くなりモードフィールドが周囲に広がろうとする。ところが、このときアンダークラッド２、５より屈折率の高い光導波路コア３が隣接して存在するため、光パワーの分布は光導波路コア４から光導波路コア３のみへ徐々に移っていく。

【００２１】テーパ部７の右端部（先端）でも一部反射が起きるが、断面が十分小さく、有効屈折率が小さくなっているため、この場所で発生する反射光はわずかである。前記とは逆に光導波路コア３の右端部から入射した場合には、ちょうど逆に、右から左へ光が進行するにつれて光導波路コア３、テーパ部７を介して、光導波路コア４へ光の分布が移動する。このように、テーパ部７を介して光導波路コア３と光導波路コア４を接続すること

で屈折率のことなる光導波路を接続する場合に適した光導波路接続構造を構成することができる。

【００２２】なお、テーパ部７は、長手方向の断面の高さをほぼ保ったまま幅のみを変化させているので、高さ方向の加工を必要としない。これによって、リソグラフィやエッチング等を用いた加工が容易にできるという利点がある。また、テーパ部７のテーパ部分は、その面状態が、その伝搬される波長に比して十分なめらかである必要があるが、作成上の必要に応じて、十分に微細な凹凸であれば存在しても構わない。また、図１ではテーパは直線で表しているが、なめらかな曲線であっても構わない。

【００２３】さらに、テーパ部７の高さは、ほぼ一定としたが、加工の結果テーパ先端部で幅が細くなる部分において、高さが減少する方向で多少変化しても、これが連続的かつゆるやかであるなら構わない。また、ここでは導波路を構成する素材としてシリコンおよび石英を挙げたが、これは一つの例示に過ぎず、ガリウム砒素やインジウム燐等他の半導体材料やガラス素材、ポリマー素材等であっても構わない。

【００２４】つぎに図２を参照して本発明における第２の実施の形態を説明する。図２（ａ）は、光導波路接続構造の正面状態を示す模式図、（ｂ）は（ａ）の平面状態を示す模式図、（ｃ）は（ａ）の右側面状態を示す模式図である。

【００２５】図２（ａ），（ｂ），（ｃ）に示すように、光導波路Ａは、平面基板１２と、この平面基板１２の一方面に形成された石英系素材よりなるアンダークラッド９と、このアンダークラッド９の一方面で中央位置に沿って矩形断面に形成された光導波路コア１０（第２コア）と、この光導波路コア１０の長手方向の端部に、その先端に向かうに従って幅寸法が小さくなるように形成されたテーパ部１３と、このテーパ部１３の一方面に接触するように石英系素材よりなる矩形断面に形成された光導波路コア１１（第１コア）と、この光導波路コア１１および前記光導波路コア１０の一面に接触するように形成された石英素材よりなるオーバークラッド８とを備えている。

【００２６】なお、テーパ部１３と光導波路コア１１の整合状態は、長手方向に沿ってその光導波路コア１１およびテーパ部１３の軸線が一致する状態で整合されていることが望ましいが、光導波路コア１１の幅内で平行方向にズレる状態であることや、また、光導波路コア１１の幅内にテーパ部１３が配置され、伝搬する光が許容範囲の損失内で適切に一方から他方に伝わることができる状態であれば良い。

【００２７】オーバークラッド８、およびアンダークラッド９、および光導波路コア１１の屈折率は、添加不純物および使用波長帯域により異なるが近赤外光の領域ではいずれもおおむね１．４から１．５程度である。

一方、光導波路コア１０の屈折率は、おおむね３．４程度である。

【００２８】光導波路コア１０は、その厚さが０．２μm程度、幅が０．４μm程度に構成されている。また、光導波路コア１１は、その厚さと幅がいずれも２μm～１０μm程度に構成されている。

【００２９】テーパ部１３は、その幅が、左端側（光導波路コア１０側）では光導波路コア１０の幅と等しく、先端側（右側）においては０．１μmあるいはそれ以下となるように構成されている。そして、このテーパ部１３は、その長さが数十μm程度から１mm程度になるように構成されている。なお、前記した各構成の寸法は、ここで挙げた寸法以外であっても構わない。

【００３０】また、図２では、アンダークラッド９の上面に凸をもうけて光導波路コア１１の下面をフラットとしたが、光導波路コア１０の厚さは、光導波路コア１１の厚さと比較すると十分に小さいので、アンダークラッド９ではなく光導波路コア１１の側に下方に凸となるように凸部を設けて、アンダークラッド９の上面を平らであるようにしても、本発明による効果に変化はないし、リソグラフィプロセス技術による製造がより容易となる。

【００３１】本実施例は、同一基板上に材質やスポットサイズの異なる第１と第２の導波路を構成し、これらを接続する部分も同一基板上に構成するものであり、低損失で接続できるという利点がある。また、テーパ部の高さ方向の加工を必要としないので、加工が容易で作りやすいという利点もある。

【００３２】つぎに、光導波路コア１０から光導波路コア１１に伝達される光の伝達状態を説明する。光導波路コア１０の左端面から入射した光は光導波路コア１０を伝搬してテーパ部１３の左端面に到達する。オーバークラッド８と光導波路コア１１の境目で一部の光が反射するが、オーバークラッド８と光導波路コア１１の屈折率の違いは、光導波路コア１０とオーバークラッド８あるいは、テーパ部１３と光導波路コア１１の屈折率の違いに比べると極めてわずかであるので、この場所で発生する反射光はごくわずかである。

【００３３】光は、テーパ部１３の幅が徐々に狭まるに従って閉じこめが弱くなり、モードフィールドが周囲に広がろうとするが、オーバークラッド８、アンダークラッド９より屈折率の高い光導波路コア１１が隣接して存在するため、光パワーの分布が光導波路コア１０からテーパ部１３を介して光導波路コア１１のみへ徐々に移っていく。光は、テーパ部１３の先端部でも一部反射を発生するが、テーパ部１３の断面が十分小さく、有効屈折率が小さくなっているため、この場所で発生する反射光はごくわずかである。

【００３４】前記とは逆に光導波路コア１１の右端部から光が入射した場合には、ちょうど逆に、右から左へ進

行するにつれて光導波路コア１１からテーパ部１３を介して光導波路コア１０へ光パワーの分布が移動する。

【００３５】テーパ部１３は、そのテーパ（傾斜）部分の面状態が、波長と比較して十分なめらかである必要があるが、製造上の必要に応じて、十分に微細な凹凸であれば存在しても構わない。また、図２ではテーパは直線で表しているが、なめらかな曲線であっても構わない。

【００３６】つぎに、図３を参照して本発明における第３の実施の形態を説明する。図３（ａ）は光導波路接続構造の正面状態を示す模式図、（ｂ）は（ａ）の光導波路接続構造の平面状態を示す模式図、（ｃ）は（ａ）の光導波路接続構造の右側面状態を示す模式図である。なお、図３では、平面基板２１の左右に離間して一体に形成された第１光導波路ｃおよび第２光導波路ｄを有する第１モジュールと、両光導波路ｃ、ｄとは別体に形成した第３光導波路ｅである第２モジュールとを接続する構成について説明する。

【００３７】第３光導波路ｅは、平面基板１４と、この平面基板１４の一方面に形成された石英系素材よりなるアンダークラッド１５と、このアンダークラッド１５の一方面で中央に沿って形成された矩形断面の光導波路コア２２（第２コア）と、この光導波路コア２２の左右に端部に向かうに従って幅が狭くなるように形成された第１テーパ部１６および第２テーパ部１７とを備えている。

【００３８】また、第１光導波路ｃおよび第２光導波路ｄは、平面基板２１およびこの平面基板２１の一方面に形成した石英系素材からなるアンダークラッド２０を共通して備えており、このアンダークラッド２０の所定位置に形成した凸部分２０ａの左右で中央に沿って矩形断面に形成された第１光導波路コア１８（第１コア）と、第２光導波路コア１９（第１コア）とを備えている。

【００３９】そして、第３光導波路ｅの第１テーパ部１６と第２テーパ部１７が、第１光導波路ｃおよび第２光導波路ｄの第１光導波路コア１８と第２光導波路コア１９の上に重なり合うように第１モジュールと第２モジュールとを精密位置決めを行い、光硬化樹脂などの接合部材を介して接合する。

【００４０】このとき、製造誤差と位置決め誤差を合わせた第１テーパ部１６と第１光導波路コア１８、第２テーパ部１７と第２光導波路コア１９の位置ズレの許容範囲量は、第１光導波路コア１８および第２光導波路コア１９の幅内に収まる程度であり、従来技術を用いた方法より格段にゆるやかである。そのため、複数の入出力光導波路を持つ半導体光回路部品を、石英型光導波路上に集積する事が容易となる。

【００４１】なお、図３では、二つの光導波路の組が同一直線上で平面基板に一体に結合しているが、３つあるいはそれ以上の光導波路の組であってもかまわないし、結合される光導波路が別々に形成される構成であってもよく、さらに、各々の光導波路の位置関係が、クラッドに形成されるテーパ部を備えるコアを複数平行・放射状などに形成し、それぞれのテーパ部に、接続するための光導波路を接触させる構成としてもよい。なお、接続させる光導波路の位置関係は、他の任意の位置関係であってもかまわない。また、光導波路コア２２は、任意の光機能部であればよく、例えば、光スイッチの構成や、あるいは、光フィルタの構成であってもよく、特に、導波路構造を持つ必要はなく、波長分散プリズム等であっても構わない。さらに、図１ないし図３では、光導波路接続構造として、それぞれの光導波路の断面形状を矩形断面として説明したが、それ以外の断面形状であっても、本発明のテーパ部を備える構成であれば、特に、その断面形状を限定されるものではない。

【００４２】

【発明の効果】本発明によれば、２つの光導波路の光結合を行う光導波路接続構造は、幅方向にテーパを形成するテーパ部を介して、入力側の光導波路の導波モードから出力側の光導波路の導波モードへ徐々に変化するため、入力側の光導波路の導波モードが出力側の光導波路の導波モードに断続的に変換される。これによって、入力側及び出力側の光導波路のスポットサイズが整合しない場合においても損失の少ない接続が可能となり、また、光の伝搬方向において反射の要因となる急激な導波路構造の変化がないため、接続部分の結合部における反射戻り光を極めて少なくでき、反射減衰量を従来技術と比べてそれ以下まで小さくすることができる。そして、光導波路接続構造は、厚さ方向の変化を伴う構造を有しないためリソグラフィプロセス技術等による製造に適し、高精度加工や大量生産が容易となる。

【００４３】また、光導波路接続構造は、接続部分の結合部における２つの光導波路は等価屈折率を特定の値に正確に調整する必要がないので、光導波路の横造を厳密に制御する必要がなく、さらにまた、結合における二つの光導波路の相対的な位置ズレ量は、コアとクラッドの比屈折率差が小さい光導波路すなわちコア断面積が大きな光導波路のコア断面積と同等程度で良いため、接続のための作業に高い精度を必要としない。

【００４４】さらに、光導波路接続構造は、同一基板上に材質やスポットサイズの異なる複数の光回路を作りこれらを同基板上で相互に接続する場合、低損失の接続構造を容易な加工で製作できるという利点がある。したがって、光導波路接続構造は、ハイブリット集積回路に最適に使用することができる。なお、光導波路接続構造は、複数の入出力光導波路を持つ半導体光回路部品を、石英型光導波路上に集積する事が容易となる。

【図面の簡単な説明】

【図１】　（ａ）は本発明にかかる第１の実施の形態における光導波路接続構造の正面状態を示す模式図、（ｂ）は（ａ）の平面状態を示す模式図、（ｃ）は

（ａ）の右側面状態を示す模式図である。

【図２】　（ａ）は、本発明にかかる第２の実施の形態における光導波路接続構造の正面状態を示す模式図、（ｂ）は（ａ）の平面状態を示す模式図、（ｃ）は（ａ）の右側面状態を示す模式図である。

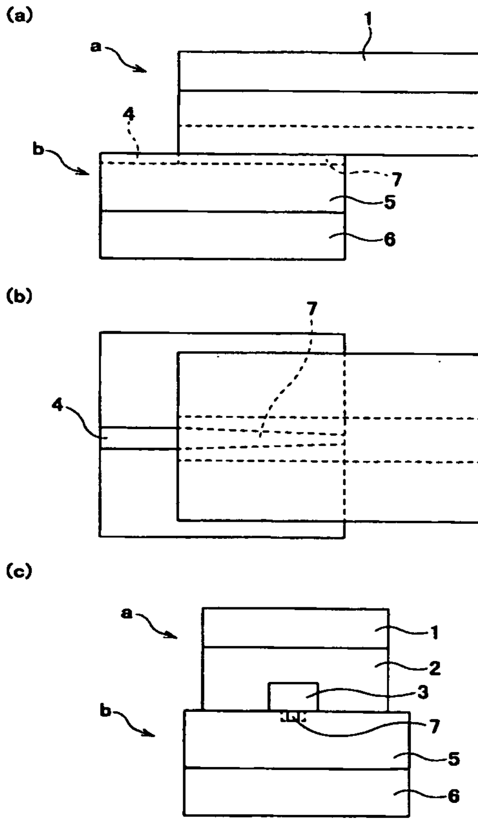
【図３】　（ａ）は、本発明にかかる第３の実施の形態における光導波路接続構造の正面状態を示す模式図、（ｂ）は（ａ）の平面状態を示す模式図、（ｃ）は（ａ）の右側面状態を示す模式図である。

【図４】　（ａ）、（ｂ）は従来の光導波路接続構造の概略図である。

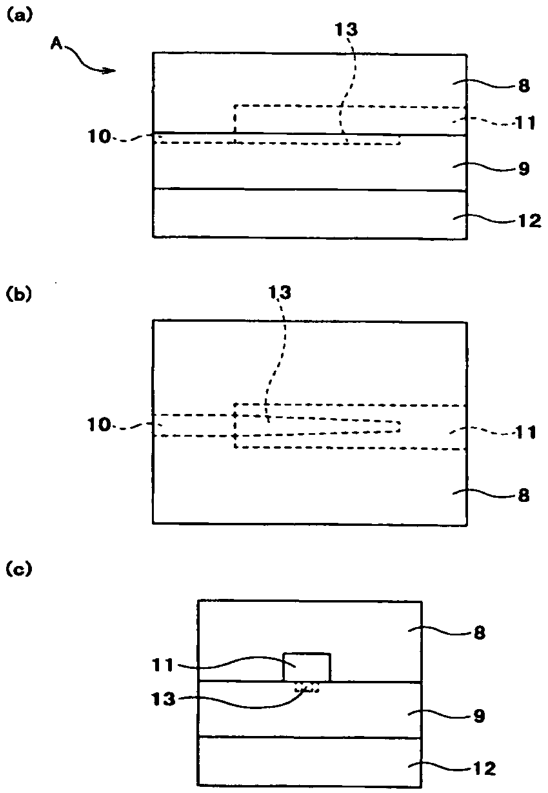
【符号の説明】

a	第１光導波路
b	第２光導波路
c	第１光導波路
d	第２光導波路
e	第３光導波路
A	光導波路（第１光導波路、第２光導波路）
１，６，１２，２１	平面基板
２，５，１５，２０	アンダークラッド
３	光導波路コア（第１コア）
４	光導波路コア（第２コア）
７，１３，１６，１７	テーパ部
８	オーバークラッド
９	アンダークラッド
１０	光導波路コア（第２コア）
１１	光導波路コア（第１コア）
１８	第１光導波路コア（第１コア）
１９	第２光導波路コア（第１コア）
２０ａ	凸部
２２	光導波路（第２コア）

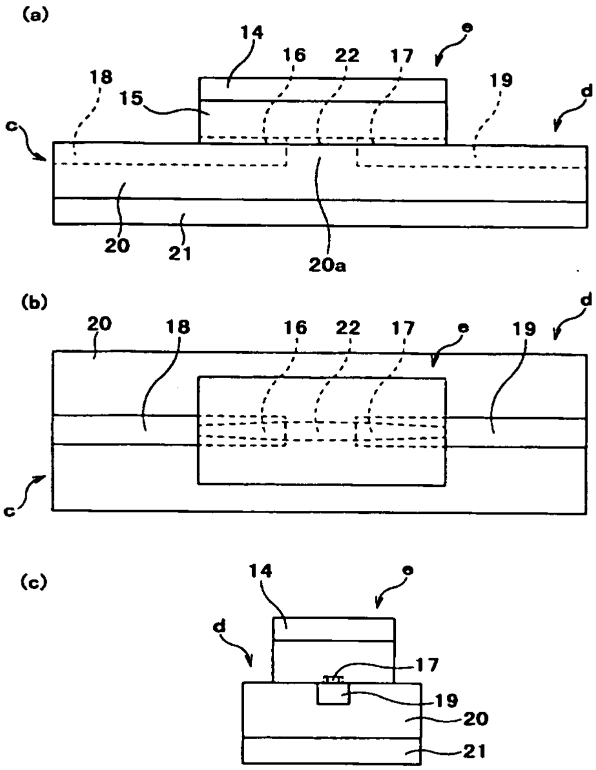
【図１】



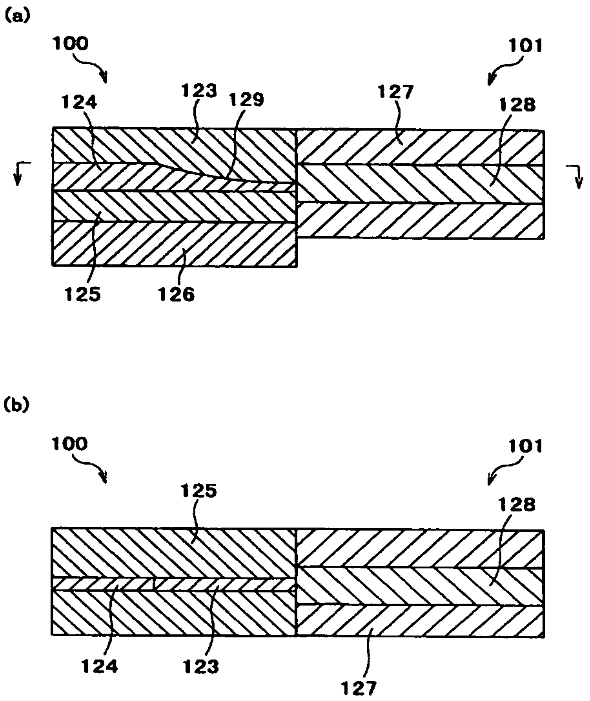
【図２】



【図３】



【図４】



フロントページの続き

(72)発明者　森田　博文
東京都千代田区大手町二丁目３番１号　日本電信電話株式会社内

(72)発明者　納富　雅也
東京都千代田区大手町二丁目３番１号　日本電信電話株式会社内

(72)発明者　新家　昭彦
東京都千代田区大手町二丁目３番１号　日本電信電話株式会社内

(72)発明者　横浜　至
東京都千代田区大手町二丁目３番１号　日本電信電話株式会社内

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CLAIMS

[Claim(s)]
[Claim 1] The 1st optical waveguide which has the 1st core which carries out guided wave propagation of the light, and a clad with a refractive index smaller than this 1st core, In the optical waveguide connection structure of connecting optically the 2nd optical waveguide which has the 2nd core with a larger refractive index than the refractive index of the 1st core of this 1st optical waveguide the 2nd core of said 2nd optical waveguide The taper section which becomes small toward the edge of the 2nd waveguide about the dimension of the cross direction where the cross-section height of a longitudinal direction is maintained is formed. The 1st core of said 1st optical waveguide, Optical waveguide connection structure characterized by being arranged so that said taper section in the 2nd core of said 2nd optical waveguide may approach a longitudinal direction optically in the state of [parallel] contact.
[Claim 2] Optical waveguide connection structure according to claim 1 characterized by consisting of the same material with which the clad which said 1st optical waveguide and said 2nd optical waveguide are formed in the same substrate, and is formed in said substrate continued.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the optical waveguide connection structure of connecting the optical waveguides which carry out guided wave propagation of the light, and relates to the optical waveguide connection structure where it was suitable when the optical waveguide from which a refractive index differs especially was connected mutually.
[0002]
[Description of the Prior Art] Advanced optical signal processing is possible for the optical integrated circuit formed by generally accumulating optical circuit elements, such as a light emitting device, a photo detector, and an optical modulator, by using flat-surface optical waveguide as a wiring member, and it is becoming the main components in optical communication from viewpoints, such as mass-production nature, stability, and cost nature. Many of optical circuit elements used for this optical integrated circuit have the waveguide structure based on structure in the slight optical closing depth by the refractive index in the interior, and efficient association with the optical waveguide which is a wiring member is called for.
[0003] On the other hand, also in the flat-surface waveguide which is a wiring member in an optical integrated circuit, from the material of the conventional quartz system, the structure of using silicon for a material is studied and connection with the existing quartz system or polymer waveguide is called for.
[0004] However, the refractive index of semi-conductors including silicon has a value big about 3 times from twice [about] in the near-infrared region chiefly used for optical communication as compared with it of a quartz system material or a polymer system material. Therefore, the ingredient of a clad is a quartz, and the cross section of the core which fulfills the single mode conditions which consist of a silicon ingredient is difficult to realize efficient association only by width of face becoming less than [about 0.4 micrometers or it], and only poking and uniting a waveguide end face, when a core cross section is a rectangle with a thickness of 0.2 micrometers. Therefore, by processing the point in the thickness direction in the shape of a taper, the waveguide core combined aimed at expansion of the diameter of the mode field, and has realized efficient association. Drawing 4 shows this conventional technique. Drawing 4 (a) and (b) are the schematic diagrams showing the side-face condition of the conventional optical waveguide connection structure.
[0005] As shown in drawing 4 (a) and (b), the waveguide core point 100 is the form put between the undershirt clad 125 and the exaggerated clad 123 on the flat-surface substrate 126, and the core section 124 with a refractive index higher than a perimeter and the taper section 129 from which the cross section changes smoothly are formed. In addition, the optical waveguides (optical fiber etc.) 101 connected to the waveguide core point 100 are equipped with the clad 127 which consists of a quartz system material, and the core section 128 which consists of a quartz system material formed inside this clad 127, and the core section 128 has the slightly bigger refractive index than a clad 127.
[0006] Therefore, the diameter of the mode field is expanded at the right end of the taper section 129 with the small cross section, and the light which carried out incidence from the left end of the core

section 124 which is optical waveguide is combined with the core section 128 which consists of a quartz system material by low loss. About 0.5dB is shown by calculated value and, as for the connection loss at this time, the numeric value of about 0.75dB is shown by the experimental value at "opto-electronics of ONU (optical network unit)" (optics volume [24th] No. 5 (May, 1995)).

[0007]

[Problem(s) to be Solved by the Invention] However, with the above mentioned conventional optical waveguide connection structure, it will be required the configuration of a taper part and that especially the cross-section configuration in a point should be processed with high degree of accuracy. Moreover, polish in a high precision was required for both of two waveguide end faces to connect, and the polish activity was serious with the aforementioned joint structure. Furthermore, it needed to position in about 1/10 precision in a core diameter with a lower refractive index, and positioning actuation was serious with the aforementioned optical waveguide connection structure.

[0008] Moreover, with the aforementioned optical waveguide connection structure, in order to compound two waveguides on the same flat-surface substrate since it is required to make the medial axis of a core with a high refractive index and a core with a low refractive index into the same flat-surface top, and to form, the complicated procedure accompanied by processing of the height direction will be required. Furthermore, with the aforementioned optical waveguide connection structure, in order to reduce both-ends face-to-face reflection loss, nonreflective coating etc. needed to be processed into the end face.

[0009] This invention is originated in view of the aforementioned trouble, and it is possible connection loss of the optical waveguides from which the spot size of the trapped mode of optical waveguide differs, and to make return loss small, and the purpose is in moreover offering easily the optical waveguide connection structure which can be manufactured with an integrated-circuit manufacture process technique, without needing a high precision for the equipment for connection, or an activity.

[0010]

[Means for Solving the Problem] In order to solve said technical problem, it constituted from this invention as follows. Namely, the 1st optical waveguide which has the 1st core which carries out guided wave propagation of the light, and a clad with a refractive index smaller than this 1st core, In the optical waveguide connection structure of connecting optically the 2nd optical waveguide which has the 2nd core with a larger refractive index than the refractive index of the 1st core of this 1st optical waveguide the 2nd core of said 2nd optical waveguide The taper section which becomes small toward the edge of the 2nd optical waveguide about the dimension of the cross direction where the cross-section height of a longitudinal direction is maintained is formed. The 1st core of said 1st optical waveguide, It considered as the optical waveguide connection structure arranged so that said taper section in the 2nd core of said 2nd waveguide may approach a longitudinal direction optically in the state of [parallel] contact.

[0011] Thus, as the trapped mode in the connection parts of this 1st core and the 2nd core goes to the side which outputs light from the side which inputs light by being constituted From a larger condition than the optical power to which the optical power which passes the core of near optical waveguide which inputs light passes the core of the optical waveguide of the side to output The optical power which passes the core of the optical waveguide of the side which outputs light comes to change to a larger condition than the optical power which passes the core of near optical waveguide to input gradually.

[0012] Moreover, in the above mentioned optical waveguide connection structure, it considered as the optical waveguide connection structure constituted so that it might consist of the same material with which the clad which said 1st optical waveguide and said 2nd optical waveguide are formed in the same substrate, and is formed in said substrate continued. Thus, by constituting, there is an advantage that it is connectable by low loss. Moreover, there is an advantage which does not need processing of the height direction of the taper section.

[0013]

[Embodiment of the Invention] Hereafter, the optical waveguide connection structure concerning this invention is explained to a detail with reference to a drawing. Drawing 1 is the gestalt of the first

operation concerning this invention. The mimetic diagram in which drawing 1 (a) shows the transverse-plane condition of optical waveguide connection structure, the mimetic diagram in which (b) shows the flat-surface condition of (a), and (c) are the mimetic diagrams showing the right lateral condition of (a).
[0014] As shown in drawing 1 (a), (b), and (c), the 1st optical waveguide a is equipped with the flat-surface substrate 1, the undershirt clad 2 which consists of a quartz system material of this flat-surface substrate 1 formed in a field on the other hand, and the optical waveguide core 3 (the 1st core) which consists of a quartz system material of this undershirt clad 2 formed along the center of a field on the other hand.
[0015] Moreover, the undershirt clad 5 which the 2nd optical waveguide b becomes from the quartz system material of the flat-surface substrate 6 and this flat-surface substrate 6 formed in a field on the other hand, The optical waveguide core 4 (the 2nd core) which consists of silicon of this undershirt clad 5 formed along a center in a field on the other hand, It has the taper section 7 formed in the edge of this optical waveguide core 4 by changing continuously so that it might become thin as a width method is gone at a tip, where the cross-section height (thickness) of that optical waveguide core 4 is maintained.
[0016] And the taper section 7 of the 2nd optical waveguide b is arranged in the condition of having been arranged so that the optical waveguide core 3 and longitudinal direction of the 1st optical waveguide a may be optically approached in the state of [parallel] contact. In addition, it is considering as the condition of having combined the 1st optical waveguide a and the 2nd optical waveguide b through connection members, such as photo-curing resin, here. the condition of shifting in parallel within the width of face of the optical waveguide core 3 although it is desirable for axes to be in agreement as for the physical relationship of the taper section 7 and the optical waveguide core 3 -- or strict adjustment is not needed that what is necessary is just in the condition which is extent to which the taper section 7 is settled in the width of face of the optical waveguide core 3. moreover, the light spread as approaching optically in the parallel condition -- the inside of loss of tolerance -- suitable -- while -- from -- it is in the condition which can get across to another side.
[0017] Although the refractive index of the undershirt clad 2 and the optical waveguide core 3, and the undershirt clad 5 changes with an addition impurity and operating wavelength bands, in the field of near-infrared light, all are 1.4 to about 1.5 in general. On the other hand, the refractive index of the optical waveguide core 4 is about 3.4 in general. The thickness of the optical waveguide core 4 is about 0.2 micrometers, width of face is about 0.4 micrometers, and each the thickness and width of face of the optical waveguide core 3 are 21 micrometers - about 10 micrometers.
[0018] Moreover, the taper section 7 is formed so that it may become less than [0.1 micrometers or it], as the width of face goes to a right end (tip) from the width of face of the optical waveguide core 4 in a left end (optical waveguide core 4 side). The die length of this taper section 7 is formed in about 1mm from about dozens of micrometers. The width of face and die length of this taper section 7 will not be especially limited, if it is formed in the dimension from which actuation becomes easy when performing positioning etc. to the near optical waveguide core which connects. In addition, the dimension of each above mentioned configuration may be except the dimension mentioned here.
[0019] Below, the propagation condition of the light in optical waveguide connection structure is explained. The light which carried out incidence from the left end side of the optical waveguide core 4 spreads the optical waveguide core 4, and arrives at the left end location of the taper section 7. Although a part of light reflects by the difference in the refractive index of the air which carries out the role of the clad of the optical waveguide core 4 in the left end of the optical waveguide core 3, and the optical waveguide core 3, since the difference in the refractive index of air and the optical waveguide core 3 is relatively small compared with the difference in the refractive index of the optical waveguide core 4, air or the taper section 7, and the optical waveguide core 3, this reflected light reinforcement is weak.
[0020] The slight closing depth of narrowing light tends to become [core width of face] weak gradually, and the mode field tends to spread around as light spreads the taper section 7 rightward in drawing 1 . However, since the optical waveguide core 3 with a refractive index higher than the undershirt clads 2 and 5 adjoins and exists at this time, it moves from distribution of optical power only to the optical waveguide core 3 gradually from the optical waveguide core 4.

[0021] Although reflection occurs in part, the right end section (tip) of the taper section 7 also has a small cross section enough, and since the effective refractive index is small, the reflected light generated in this location is slight [section]. When incidence is carried out from the right end section of the optical waveguide core 3 contrary to the above, distribution of light moves to the optical waveguide core 4 through the optical waveguide core 3 and the taper section 7 conversely exactly as light advances from the right to the left. thus, the thing for which the optical waveguide core 3 and the optical waveguide core 4 are connected through the taper section 7 -- a refractive index -- things -- the optical waveguide connection structure where it was suitable when optical waveguide was connected can be constituted.
[0022] In addition, since the taper section 7 is changing only width of face, maintaining the height of the cross section of a longitudinal direction mostly, it does not need processing of the height direction. There is an advantage that processing using lithography, etching, etc. can be easily performed by this. Moreover, although the field condition of the taper part of the taper section 7 needs to be smooth enough as compared with the wavelength spread, as long as it is irregularity detailed enough if needed on creation, you may exist. Moreover, although the taper is expressed with drawing 1 in a straight line, in it, it may be a smooth curve.
[0023] furthermore, although considered as about 1 law, even if it changes somewhat towards height decreasing in the part to which width of face becomes thin by the taper point as a result of processing, if the height of the taper section 7 has this continuous and loose, it will not be cared about. Moreover, although silicon and a quartz were mentioned as a material which constitutes waveguide here, it may not pass over this to one instantiation, but it may be other semiconductor materials, a glass material, polymer materials, etc., such as gallium arsenide and indium phosphide.
[0024] With reference to drawing 2 , the gestalt of the 2nd operation in this invention is explained below. The mimetic diagram in which drawing 2 (a) shows the transverse-plane condition of optical waveguide connection structure, the mimetic diagram in which (b) shows the flat-surface condition of (a), and (c) are the mimetic diagrams showing the right lateral condition of (a).
[0025] As shown in drawing 2 (a), (b), and (c), optical waveguide A The flat-surface substrate 12 and the undershirt clad 9 which consists of a quartz system material of this flat-surface substrate 12 formed in the field on the other hand, The optical waveguide core 10 (the 2nd core) of this undershirt clad 9 formed in the rectangle cross section along with the mid gear in the field on the other hand, The taper section 13 formed in the edge of the longitudinal direction of this optical waveguide core 10 so that a width method might become small as it went at that tip, It has the exaggerated clad 8 which consists of a quartz material formed so that the whole surface of the optical waveguide core 11 (the 1st core) formed in the rectangle cross section of this taper section 13 which consists of a quartz system material so that a field may be contacted on the other hand, and the this optical waveguide core 11 and said optical waveguide core 10 might be contacted.
[0026] in addition, although it is desirable to have consistency in the condition that the axis of the optical waveguide core 11 and the taper section 13 is in agreement along with a longitudinal direction as for the adjustment condition of the taper section 13 and the optical waveguide core 11, it is in the condition which shifts in parallel within the width of face of the optical waveguide core 11 -- moreover, the light which the taper section 13 is arranged in the width of face of the optical waveguide core 11, and spreads -- the inside of loss of tolerance -- suitable -- while -- from -- what is necessary is just in the condition which can get across to another side
[0027] Although the refractive index of the exaggerated clad 8, the undershirt clad 9, and the optical waveguide core 11 changes with an addition impurity and operating wavelength bands, in the field of near-infrared light, all are 1.4 to about 1.5 in general. On the other hand, the refractive index of the optical waveguide core 10 is about 3.4 in general.
[0028] The thickness is constituted by about 0.2 micrometers and, as for the optical waveguide core 10, width of face is constituted by about 0.4 micrometers. Moreover, as for the optical waveguide core 11, each of the thickness and width of face are constituted by 2 micrometers - about 10 micrometers.
[0029] It is constituted so that the width of face of the taper section 13 may be equal to the width of face of the optical waveguide core 10 in a left end side (optical waveguide core 10 side) and it may become

less than [0.1 micrometers or it] at a tip side (right-hand side). And this taper section 13 is constituted so that that die length may be set to about 1mm from about dozens of micrometers. In addition, the dimension of each above mentioned configuration may be except the dimension mentioned here.

[0030] Moreover, although the convex was prepared in the top face of the undershirt clad 9 and the inferior surface of tongue of the optical waveguide core 11 was made into the flat in drawing 2 Since the thickness of the optical waveguide core 10 is fully small as compared with the thickness of the optical waveguide core 11 Heights are prepared so that it may be on the optical waveguide core 11 side instead of the undershirt clad 9 with a convex caudad, and in the top face of the undershirt clad 9, even if it makes it like, it is changeless in the even effectiveness by this invention, and manufacture by the lithography process technique becomes easier.

[0031] This example constitutes the 1st and the 2nd waveguide from which the quality of the material and spot size differ on the same substrate, also constitutes the part which connects these on the same substrate, and has the advantage that it is connectable by low loss. Moreover, since processing of the height direction of the taper section is not needed, there is also an advantage of processing being easy and being easy to make it.

[0032] Below, the transfer condition of the light transmitted to the optical waveguide core 11 from the optical waveguide core 10 is explained. The light which carried out incidence from the left end side of the optical waveguide core 10 spreads the optical waveguide core 10, and arrives at the left end side of the taper section 13. Although a part of light reflects on the boundary line of the exaggerated clad 8 and the optical waveguide core 11, since the differences in the refractive index of the exaggerated clad 8 and the optical waveguide core 11 are very few compared with the difference in the refractive index of the optical waveguide core 10, the exaggerated clad 8, or the taper section 13 and the optical waveguide core 11, the reflected light generated in this location is very slight.

[0033] Although light tends to be closed as the width of face of the taper section 13 narrows gradually, slight depth tends to become weak and the mode field tends to spread around, since the optical waveguide core 11 with a refractive index higher than the exaggerated clad 8 and the undershirt clad 9 adjoins and exists, distribution of optical power moves from the optical waveguide core 10 only to the optical waveguide core 11 gradually through the taper section 13. Although light generates reflection in part also in the point of the taper section 13, the cross section of the taper section 13 is small enough, and since the effective refractive index is small, the reflected light generated in this location is very slight.

[0034] When light carries out incidence from the right end section of the optical waveguide core 11 contrary to the above, distribution of optical power moves to the optical waveguide core 10 through the taper section 13 conversely from the optical waveguide core 11 exactly as it goes on from the right to the left.

[0035] You may exist, as long as it is irregularity detailed enough if needed on manufacture, although the taper section 13 needs to have enough the smooth field condition of the taper (inclination) part as compared with wavelength. Moreover, although the taper is expressed with drawing 2 in a straight line, in it, it may be a smooth curve.

[0036] Below, with reference to drawing 3 , the gestalt of the 3rd operation in this invention is explained. The mimetic diagram in which drawing 3 (a) shows the transverse-plane condition of optical waveguide connection structure, the mimetic diagram in which (b) shows the flat-surface condition of the optical waveguide connection structure of (a), and (c) are the mimetic diagrams showing the right lateral condition of the optical waveguide connection structure of (a). In addition, by drawing 3 , the 1st module which has the 1st optical waveguide c which estranged to right and left of the flat-surface substrate 21, and was formed in one, and the 2nd optical waveguide d, and both the optical waveguides c and d explain the configuration which connects the 2nd module which is the 3rd optical waveguide e formed in another object.

[0037] The undershirt clad 15 which the 3rd optical waveguide e becomes from the quartz system material of the flat-surface substrate 14 and this flat-surface substrate 14 formed in the field on the other hand, It has the 1st taper section 16 and the 2nd taper section 17 which were formed so that width of face might become narrow as it goes to right and left of the optical waveguide core 22 (the 2nd core) of the rectangle cross section of this undershirt clad 15 formed along the center in the field on the other hand, and this optical waveguide core 22 at the edge.

[0038] Moreover, the 1st optical waveguide c and the 2nd optical waveguide d It has in common the undershirt clad 20 which consists of a flat-surface substrate 21 and a quartz system material of this flat-surface substrate 21 formed in the field on the other hand. It has the 1st optical waveguide core 18 (the 1st core) formed in the rectangle cross section along the center by right and left of heights part 20a formed in the predetermined location of this undershirt clad 20, and the 2nd optical waveguide core 19 (the 1st core).

[0039] And the 1st taper section 16 and the 2nd taper section 17 of the 3rd optical waveguide e perform precision positioning, and join the 1st module and the 2nd module through joint material, such as photo-curing resin, so that it may overlap on the 1st optical waveguide core 18 of the 1st optical waveguide c and the 2nd optical waveguide d, and the 2nd optical waveguide core 19.

[0040] at this time, the amount of tolerance of location gap of the 1st taper section 16 which doubled the manufacture error and the locational error, the 1st optical waveguide core 18 and the 2nd taper section 17, and the 2nd optical waveguide core 19 is extent settled in the width of face of the 1st optical waveguide core 18 and the 2nd optical waveguide core 19, and is alike and looser than the approach using the conventional technique. Therefore, it becomes easy to accumulate semi-conductor optical circuit components with two or more I/O optical waveguides on quartz mold optical waveguide.

[0041] In addition, although the group of two optical waveguides has combined with the flat-surface substrate on the same straight line in drawing 3 at one You may be the group of the optical waveguide beyond three or it, and may be the configuration that the optical waveguide combined is formed separately. Furthermore, it is good also as a configuration in which the optical waveguide for forming in two or more parallel, a radial, etc. the core which the physical relationship of each optical waveguide equips with the taper section formed in a clad, and connecting with each taper section is contacted. In addition, the physical relationship of the optical waveguide to connect may be the physical relationship of other arbitration. moreover, the optical waveguide core 22 -- the optical function part of arbitration -- it is -- ****ing -- for example, the configuration of an optical switch -- or it is not necessary to have waveguide structure, and you may be the configuration of an optical filter, and it does not matter especially even if it is wavelength dispersion prism etc. Furthermore, in drawing 1 thru/or drawing 3 , as optical waveguide connection structure, although the cross-section configuration of each optical waveguide was explained as a rectangle cross section, even if it is the other cross-section configuration, if it is a configuration equipped with the taper section of this invention, the cross-section configuration will not be limited especially.

[0042]

[Effect of the Invention] the taper section in which the optical waveguide connection structure of performing optical coupling of two optical waveguides forms a taper crosswise according to this invention -- minding -- guided wave MODOHE of the optical waveguide of the trapped mode of the optical waveguide of an input side to an output side -- in order to change gradually, the trapped mode of the optical waveguide of an input side is intermittently changed into the trapped mode of the optical waveguide of an output side. By this, since there is no rapid change of waveguide structure which little connection of loss of is attained and causes reflective in the propagation direction of light when the spot size of the optical waveguide of an input side and an output side does not have consistency, reflective return light in the bond part of a connection part can be lessened extremely, and return loss can be made small to less than [it] compared with the conventional technique. And since optical waveguide connection structure does not have the structure accompanied by change of the thickness direction, it is suitable for manufacture by a lithography process technique etc., and it becomes easy high precision processing and to mass-produce it.

[0043] Moreover, since two optical waveguides in the bond part of a connection part do not need to adjust an effective refractive index to a specific value correctly, optical waveguide connection structure It is not necessary to control **** of optical waveguide strictly, and the relative amount of location gaps of two optical waveguides in association further again With the core cross section and equivalent extent of big, the optical waveguide with small relative index difference, i.e., the core cross section, of a core and a clad, optical waveguide, since it is good, a high precision is not needed for the activity for connection.

[0044] Furthermore, optical waveguide connection structure has the advantage that the connection structure of low loss can be manufactured by easy processing, when making two or more optical circuits where the quality of the material differs from spot size on the same substrate and connecting these mutually on this substrate. Therefore, optical waveguide connection structure can be used the the best for a high Brit integrated circuit. In addition, optical waveguide connection structure becomes easy [accumulating semi-conductor optical circuit components with two or more I/O optical waveguides on quartz mold optical waveguide].

[Translation done.]

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TECHNICAL FIELD

[Field of the Invention] This invention relates to the optical waveguide connection structure of connecting the optical waveguides which carry out guided wave propagation of the light, and relates to the optical waveguide connection structure where it was suitable when the optical waveguide from which a refractive index differs especially was connected mutually.

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PRIOR ART

[Description of the Prior Art] Advanced optical signal processing is possible for the optical integrated circuit formed by generally accumulating optical circuit elements, such as a light emitting device, a photo detector, and an optical modulator, by using flat-surface optical waveguide as a wiring member, and it is becoming the main components in optical communication from viewpoints, such as mass-production nature, stability, and cost nature. Many of optical circuit elements used for this optical integrated circuit have the waveguide structure based on structure in the slight optical closing depth by the refractive index in the interior, and efficient association with the optical waveguide which is a wiring member is called for.
[0003] On the other hand, also in the flat-surface waveguide which is a wiring member in an optical integrated circuit, from the material of the conventional quartz system, the structure of using silicon for a material is studied and connection with the existing quartz system or polymer waveguide is called for.
[0004] However, the refractive index of semi-conductors including silicon has a value big about 3 times from twice [about] in the near-infrared region chiefly used for optical communication as compared with it of a quartz system material or a polymer system material. Therefore, the ingredient of a clad is a quartz, and the cross section of the core which fulfills the single mode conditions which consist of a silicon ingredient is difficult to realize efficient association only by width of face becoming less than [about 0.4 micrometers or it], and only poking and uniting a waveguide end face, when a core cross section is a rectangle with a thickness of 0.2 micrometers. Therefore, by processing the point in the thickness direction in the shape of a taper, the waveguide core combined aimed at expansion of the diameter of the mode field, and has realized efficient association. Drawing 4 shows this conventional technique. Drawing 4 (a) and (b) are the schematic diagrams showing the side-face condition of the conventional optical waveguide connection structure.
[0005] As shown in drawing 4 (a) and (b), the waveguide core point 100 is the form put between the undershirt clad 125 and the exaggerated clad 123 on the flat-surface substrate 126, and the core section 124 with a refractive index higher than a perimeter and the taper section 129 from which the cross section changes smoothly are formed. In addition, the optical waveguides (optical fiber etc.) 101 connected to the waveguide core point 100 are equipped with the clad 127 which consists of a quartz system material, and the core section 128 which consists of a quartz system material formed inside this clad 127, and the core section 128 has the slightly bigger refractive index than a clad 127.
[0006] Therefore, the diameter of the mode field is expanded at the right end of the taper section 129 with the small cross section, and the light which carried out incidence from the left end of the core section 124 which is optical waveguide is combined with the core section 128 which consists of a quartz system material by low loss. the connection loss at this time -- for example

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EFFECT OF THE INVENTION

[Effect of the Invention] the taper section in which the optical waveguide connection structure of performing optical coupling of two optical waveguides forms a taper crosswise according to this invention -- minding -- guided wave MODOHE of the optical waveguide of the trapped mode of the optical waveguide of an input side to an output side -- in order to change gradually, the trapped mode of the optical waveguide of an input side is intermittently changed into the trapped mode of the optical waveguide of an output side. By this, since there is no rapid change of waveguide structure which little connection of loss of is attained and causes reflective in the propagation direction of light when the spot size of the optical waveguide of an input side and an output side does not have consistency, reflective return light in the bond part of a connection part can be lessened extremely, and return loss can be made small to less than [it] compared with the conventional technique. And since optical waveguide connection structure does not have the structure accompanied by change of the thickness direction, it is suitable for manufacture by a lithography process technique etc., and it becomes easy high precision processing and to mass-produce it.
[0043] Moreover, since two optical waveguides in the bond part of a connection part do not need to adjust an effective refractive index to a specific value correctly, optical waveguide connection structure It is not necessary to control **** of optical waveguide strictly, and the relative amount of location gaps of two optical waveguides in association further again With the core cross section and equivalent extent of big, the optical waveguide with small relative index difference, i.e., the core cross section, of a core and a clad, optical waveguide, since it is good, a high precision is not needed for the activity for connection.
[0044] Furthermore, optical waveguide connection structure has the advantage that the connection structure of low loss can be manufactured by easy processing, when making two or more optical circuits where the quality of the material differs from spot size on the same substrate and connecting these mutually on this substrate. Therefore, optical waveguide connection structure can be used the the best for a high Brit integrated circuit. In addition, optical waveguide connection structure becomes easy [accumulating semi-conductor optical circuit components with two or more I/O optical waveguides on quartz mold optical waveguide].

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MEANS

[Means for Solving the Problem] In order to solve said technical problem, it constituted from this invention as follows. Namely, the 1st optical waveguide which has the 1st core which carries out guided wave propagation of the light, and a clad with a refractive index smaller than this 1st core, In the optical waveguide connection structure of connecting optically the 2nd optical waveguide which has the 2nd core with a larger refractive index than the refractive index of the 1st core of this 1st optical waveguide the 2nd core of said 2nd optical waveguide The taper section which becomes small toward the edge of the 2nd optical waveguide about the dimension of the cross direction where the cross-section height of a longitudinal direction is maintained is formed. The 1st core of said 1st optical waveguide, It considered as the optical waveguide connection structure arranged so that said taper section in the 2nd core of said 2nd waveguide may approach a longitudinal direction optically in the state of [parallel] contact.
[0011] Thus, as the trapped mode in the connection parts of this 1st core and the 2nd core goes to the side which outputs light from the side which inputs light by being constituted From a larger condition than the optical power to which the optical power which passes the core of near optical waveguide which inputs light passes the core of the optical waveguide of the side to output The optical power which passes the core of the optical waveguide of the side which outputs light comes to change to a larger condition than the optical power which passes the core of near optical waveguide to input gradually.
[0012] Moreover, in the above mentioned optical waveguide connection structure, it considered as the optical waveguide connection structure constituted so that it might consist of the same material with which the clad which said 1st optical waveguide and said 2nd optical waveguide are formed in the same substrate, and is formed in said substrate continued. Thus, by constituting, there is an advantage that it is connectable by low loss. Moreover, there is an advantage which does not need processing of the height direction of the taper section.
[0013]
[Embodiment of the Invention] Hereafter, the optical waveguide connection structure concerning this invention is explained to a detail with reference to a drawing. Drawing 1 is the gestalt of the first operation concerning this invention. The mimetic diagram in which drawing 1 (a) shows the transverse-plane condition of optical waveguide connection structure, the mimetic diagram in which (b) shows the flat-surface condition of (a), and (c) are the mimetic diagrams showing the right lateral condition of (a).
[0014] As shown in drawing 1 (a), (b), and (c), the 1st optical waveguide a is equipped with the flat-surface substrate 1, the undershirt clad 2 which consists of a quartz system material of this flat-surface substrate 1 formed in a field on the other hand, and the optical waveguide core 3 (the 1st core) which consists of a quartz system material of this undershirt clad 2 formed along the center of a field on the other hand.
[0015] Moreover, the undershirt clad 5 which the 2nd optical waveguide b becomes from the quartz system material of the flat-surface substrate 6 and this flat-surface substrate 6 formed in a field on the other hand, The optical waveguide core 4 (the 2nd core) which consists of silicon of this undershirt clad 5 formed along a center in a field on the other hand, It has the taper section 7 formed in the edge of this

optical waveguide core 4 by changing continuously so that it might become thin as a width method is gone at a tip, where the cross-section height (thickness) of that optical waveguide core 4 is maintained.
[0016] And the taper section 7 of the 2nd optical waveguide b is arranged in the condition of having been arranged so that the optical waveguide core 3 and longitudinal direction of the 1st optical waveguide a may be optically approached in the state of [parallel] contact. In addition, it is considering as the condition of having combined the 1st optical waveguide a and the 2nd optical waveguide b through connection members, such as photo-curing resin, here. the condition of shifting in parallel within the width of face of the optical waveguide core 3 although it is desirable for axes to be in agreement as for the physical relationship of the taper section 7 and the optical waveguide core 3 -- or strict adjustment is not needed that what is necessary is just in the condition which is extent to which the taper section 7 is settled in the width of face of the optical waveguide core 3. moreover, the light spread as approaching optically in the parallel condition -- the inside of loss of tolerance -- suitable -- while -- from -- it is in the condition which can get across to another side.
[0017] Although the refractive index of the undershirt clad 2 and the optical waveguide core 3, and the undershirt clad 5 changes with an addition impurity and operating wavelength bands, in the field of near-infrared light, all are 1.4 to about 1.5 in general. On the other hand, the refractive index of the optical waveguide core 4 is about 3.4 in general. The thickness of the optical waveguide core 4 is about 0.2 micrometers, width of face is about 0.4 micrometers, and each the thickness and width of face of the optical waveguide core 3 are 21 micrometers - about 10 micrometers.
[0018] Moreover, the taper section 7 is formed so that it may become less than [0.1 micrometers or it], as the width of face goes to a right end (tip) from the width of face of the optical waveguide core 4 in a left end (optical waveguide core 4 side). The die length of this taper section 7 is formed in about 1mm from about dozens of micrometers. The width of face and die length of this taper section 7 will not be especially limited, if it is formed in the dimension from which actuation becomes easy when performing positioning etc. to the near optical waveguide core which connects. In addition, the dimension of each above mentioned configuration may be except the dimension mentioned here.
[0019] Below, the propagation condition of the light in optical waveguide connection structure is explained. The light which carried out incidence from the left end side of the optical waveguide core 4 spreads the optical waveguide core 4, and arrives at the left end location of the taper section 7. Although a part of light reflects by the difference in the refractive index of the air which carries out the role of the clad of the optical waveguide core 4 in the left end of the optical waveguide core 3, and the optical waveguide core 3, since the difference in the refractive index of air and the optical waveguide core 3 is relatively small compared with the difference in the refractive index of the optical waveguide core 4, air or the taper section 7, and the optical waveguide core 3, this reflected light reinforcement is weak.
[0020] The slight closing depth of narrowing light tends to become [core width of face] weak gradually, and the mode field tends to spread around as light spreads the taper section 7 rightward in drawing 1 . However, since the optical waveguide core 3 with a refractive index higher than the undershirt clads 2 and 5 adjoins and exists at this time, it moves from distribution of optical power only to the optical waveguide core 3 gradually from the optical waveguide core 4.
[0021] Although reflection occurs in part, the right end section (tip) of the taper section 7 also has a small cross section enough, and since the effective refractive index is small, the reflected light generated in this location is slight [section]. When incidence is carried out from the right end section of the optical waveguide core 3 contrary to the above, distribution of light moves to the optical waveguide core 4 through the optical waveguide core 3 and the taper section 7 conversely exactly as light advances from the right to the left. thus, the thing for which the optical waveguide core 3 and the optical waveguide core 4 are connected through the taper section 7 -- a refractive index -- things -- the optical waveguide connection structure where it was suitable when optical waveguide was connected can be constituted.
[0022] In addition, since the taper section 7 is changing only width of face, maintaining the height of the cross section of a longitudinal direction mostly, it does not need processing of the height direction. There is an advantage that processing using lithography, etching, etc. can be easily performed by this. Moreover, although the field condition of the taper part of the taper section 7 needs to be smooth enough

as compared with the wavelength spread, as long as it is irregularity detailed enough if needed on creation, you may exist. Moreover, although the taper is expressed with drawing 1 in a straight line, in it, it may be a smooth curve.

[0023] furthermore, although considered as about 1 law, even if it changes somewhat towards height decreasing in the part to which width of face becomes thin by the taper point as a result of processing, if the height of the taper section 7 has this continuous and loose, it will not be cared about. Moreover, although silicon and a quartz were mentioned as a material which constitutes waveguide here, it may not pass over this to one instantiation, but it may be other semiconductor materials, a glass material, polymer materials, etc., such as gallium arsenide and indium phosphide.

[0024] With reference to drawing 2 , the gestalt of the 2nd operation in this invention is explained below. The mimetic diagram in which drawing 2 (a) shows the transverse-plane condition of optical waveguide connection structure, the mimetic diagram in which (b) shows the flat-surface condition of (a), and (c) are the mimetic diagrams showing the right lateral condition of (a).

[0025] As shown in drawing 2 (a), (b), and (c), optical waveguide A The flat-surface substrate 12 and the undershirt clad 9 which consists of a quartz system material of this flat-surface substrate 12 formed in the field on the other hand, The optical waveguide core 10 (the 2nd core) of this undershirt clad 9 formed in the rectangle cross section along with the mid gear in the field on the other hand, The taper section 13 formed in the edge of the longitudinal direction of this optical waveguide core 10 so that a width method might become small as it went at that tip, It has the exaggerated clad 8 which consists of a quartz material formed so that the whole surface of the optical waveguide core 11 (the 1st core) formed in the rectangle cross section of this taper section 13 which consists of a quartz system material so that a field may be contacted on the other hand, and the this optical waveguide core 11 and said optical waveguide core 10 might be contacted.

[0026] in addition, although it is desirable to have consistency in the condition that the axis of the optical waveguide core 11 and the taper section 13 is in agreement along with a longitudinal direction as for the adjustment condition of the taper section 13 and the optical waveguide core 11, it is in the condition which shifts in parallel within the width of face of the optical waveguide core 11 -- moreover, the light which the taper section 13 is arranged in the width of face of the optical waveguide core 11, and spreads -- the inside of loss of tolerance -- suitable -- while -- from -- what is necessary is just in the condition which can get across to another side

[0027] Although the refractive index of the exaggerated clad 8, the undershirt clad 9, and the optical waveguide core 11 changes with an addition impurity and operating wavelength bands, in the field of near-infrared light, all are 1.4 to about 1.5 in general. On the other hand, the refractive index of the optical waveguide core 10 is about 3.4 in general.

[0028] The thickness is constituted by about 0.2 micrometers and, as for the optical waveguide core 10, width of face is constituted by about 0.4 micrometers. Moreover, as for the optical waveguide core 11, each of the thickness and width of face are constituted by 2 micrometers - about 10 micrometers.

[0029] It is constituted so that the width of face of the taper section 13 may be equal to the width of face of the optical waveguide core 10 in a left end side (optical waveguide core 10 side) and it may become less than [0.1 micrometers or it] at a tip side (right-hand side). And this taper section 13 is constituted so that that die length may be set to about 1mm from about dozens of micrometers. In addition, the dimension of each above mentioned configuration may be except the dimension mentioned here.

[0030] Moreover, although the convex was prepared in the top face of the undershirt clad 9 and the inferior surface of tongue of the optical waveguide core 11 was made into the flat in drawing 2 Since the thickness of the optical waveguide core 10 is fully small as compared with the thickness of the optical waveguide core 11 Heights are prepared so that it may be on the optical waveguide core 11 side instead of the undershirt clad 9 with a convex caudad, and in the top face of the undershirt clad 9, even if it makes it like, it is changeless in the even effectiveness by this invention, and manufacture by the lithography process technique becomes easier.

[0031] This example constitutes the 1st and the 2nd waveguide from which the quality of the material and spot size differ on the same substrate, also constitutes the part which connects these on the same substrate, and has the advantage that it is connectable by low loss. Moreover, since processing of the height direction of the taper section is not needed, there is also an advantage of processing being easy and being easy to make it.

[0032] Below, the transfer condition of the light transmitted to the optical waveguide core 11 from the optical waveguide core 10 is explained. The light which carried out incidence from the left end side of the optical waveguide core 10 spreads the optical waveguide core 10, and arrives at the left end side of the taper section 13. Although a part of light reflects on the boundary line of the exaggerated clad 8 and the optical waveguide core 11, since the differences in the refractive index of the exaggerated clad 8 and the optical waveguide core 11 are very few compared with the difference in the refractive index of the optical waveguide core 10, the exaggerated clad 8, or the taper section 13 and the optical waveguide core 11, the reflected light generated in this location is very slight.

[0033] Although light tends to be closed as the width of face of the taper section 13 narrows gradually, slight depth tends to become weak and the mode field tends to spread around, since the optical waveguide core 11 with a refractive index higher than the exaggerated clad 8 and the undershirt clad 9 adjoins and exists, distribution of optical power moves from the optical waveguide core 10 only to the optical waveguide core 11 gradually through the taper section 13. Although light generates reflection in part also in the point of the taper section 13, the cross section of the taper section 13 is small enough, and since the effective refractive index is small, the reflected light generated in this location is very slight.

[0034] When light carries out incidence from the right end section of the optical waveguide core 11 contrary to the above, distribution of optical power moves to the optical waveguide core 10 through the taper section 13 conversely from the optical waveguide core 11 exactly as it goes on from the right to the left.

[0035] You may exist, as long as it is irregularity detailed enough if needed on manufacture, although the taper section 13 needs to have enough the smooth field condition of the taper (inclination) part as compared with wavelength. Moreover, although the taper is expressed with drawing 2 in a straight line, in it, it may be a smooth curve.

[0036] Below, with reference to drawing 3 , the gestalt of the 3rd operation in this invention is explained. The mimetic diagram in which drawing 3 (a) shows the transverse-plane condition of optical waveguide connection structure, the mimetic diagram in which (b) shows the flat-surface condition of the optical waveguide connection structure of (a), and (c) are the mimetic diagrams showing the right lateral condition of the optical waveguide connection structure of (a). In addition, by drawing 3 , the 1st module which has the 1st optical waveguide c which estranged to right and left of the flat-surface substrate 21, and was formed in one, and the 2nd optical waveguide d, and both the optical waveguides c and d explain the configuration which connects the 2nd module which is the 3rd optical waveguide e formed in another object.

[0037] The undershirt clad 15 which the 3rd optical waveguide e becomes from the quartz system material of the flat-surface substrate 14 and this flat-surface substrate 14 formed in the field on the other hand, It has the 1st taper section 16 and the 2nd taper section 17 which were formed so that width of face might become narrow as it goes to right and left of the optical waveguide core 22 (the 2nd core) of the rectangle cross section of this undershirt clad 15 formed along the center in the field on the other hand, and this optical waveguide core 22 at the edge.

[0038] Moreover, the 1st optical waveguide c and the 2nd optical waveguide d It has in common the undershirt clad 20 which consists of a flat-surface substrate 21 and a quartz system material of this flat-surface substrate 21 formed in the field on the other hand. It has the 1st optical waveguide core 18 (the 1st core) formed in the rectangle cross section along the center by right and left of heights part 20a formed in the predetermined location of this undershirt clad 20, and the 2nd optical waveguide core 19 (the 1st core).

[0039] And the 1st taper section 16 and the 2nd taper section 17 of the 3rd optical waveguide e perform precision positioning, and join the 1st module and the 2nd module through joint material, such as photo-curing resin, so that it may overlap on the 1st optical waveguide core 18 of the 1st optical waveguide c

and the 2nd optical waveguide d, and the 2nd optical waveguide core 19.
[0040] at this time, the amount of tolerance of location gap of the 1st taper section 16 which doubled the manufacture error and the locational error, the 1st optical waveguide core 18 and the 2nd taper section 17, and the 2nd optical waveguide core 19 is extent settled in the width of face of the 1st optical waveguide core 18 and the 2nd optical waveguide core 19, and is alike and looser than the approach using the conventional technique. Therefore, it becomes easy to accumulate semi-conductor optical circuit components with two or more I/O optical waveguides on quartz mold optical waveguide.
[0041] In addition, although the group of two optical waveguides has combined with the flat-surface substrate on the same straight line in drawing 3 at one You may be the group of the optical waveguide beyond three or it, and may be the configuration that the optical waveguide combined is formed separately. Furthermore, it is good also as a configuration in which the optical waveguide for forming in two or more parallel, a radial, etc. the core which the physical relationship of each optical waveguide equips with the taper section formed in a clad, and connecting with each taper section is contacted. In addition, the physical relationship of the optical waveguide to connect may be the physical relationship of other arbitration. moreover, the optical waveguide core 22 -- the optical function part of arbitration -- it is -- ****ing -- for example, the configuration of an optical switch -- or it is not necessary to have waveguide structure, and you may be the configuration of an optical filter, and it does not matter especially even if it is wavelength dispersion prism etc. Furthermore, in drawing 1 thru/or drawing 3 , as optical waveguide connection structure, although the cross-section configuration of each optical waveguide was explained as a rectangle cross section, even if it is the other cross-section configuration, if it is a configuration equipped with the taper section of this invention, the cross-section configuration will not be limited especially.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The mimetic diagram showing the transverse-plane condition of the optical waveguide connection structure in the gestalt of the 1st operation which (a) requires for this invention, the mimetic diagram in which (b) shows the flat-surface condition of (a), and (c) are the mimetic diagrams showing the right lateral condition of (a).
[Drawing 2] The mimetic diagram showing the transverse-plane condition of the optical waveguide connection structure in the gestalt of the 2nd operation which (a) requires for this invention, the mimetic diagram in which (b) shows the flat-surface condition of (a), and (c) are the mimetic diagrams showing the right lateral condition of (a).
[Drawing 3] The mimetic diagram showing the transverse-plane condition of the optical waveguide connection structure in the gestalt of the 3rd operation which (a) requires for this invention, the mimetic diagram in which (b) shows the flat-surface condition of (a), and (c) are the mimetic diagrams showing the right lateral condition of (a).
[Drawing 4] (a) and (b) are the schematic diagrams of the conventional optical waveguide connection structure.
[Description of Notations]
The 1st optical waveguide
b The 2nd optical waveguide
c The 1st optical waveguide
d The 2nd optical waveguide
e The 3rd optical waveguide
A Optical waveguide (the 1st optical waveguide, the 2nd optical waveguide)
1, 6, 12, 21 Flat-surface substrate
2, 5, 15, 20 Undershirt clad
3 Optical Waveguide Core (1st Core)
4 Optical Waveguide Core (2nd Core)
7, 13, 16, 17 Taper section
8 Exaggerated Clad
9 Undershirt Clad
10 Optical Waveguide Core (2nd Core)
11 Optical Waveguide Core (1st Core)
18 1st Optical Waveguide Core (1st Core)
19 2nd Optical Waveguide Core (1st Core)
20a Heights
22 Optical Waveguide (2nd Core)

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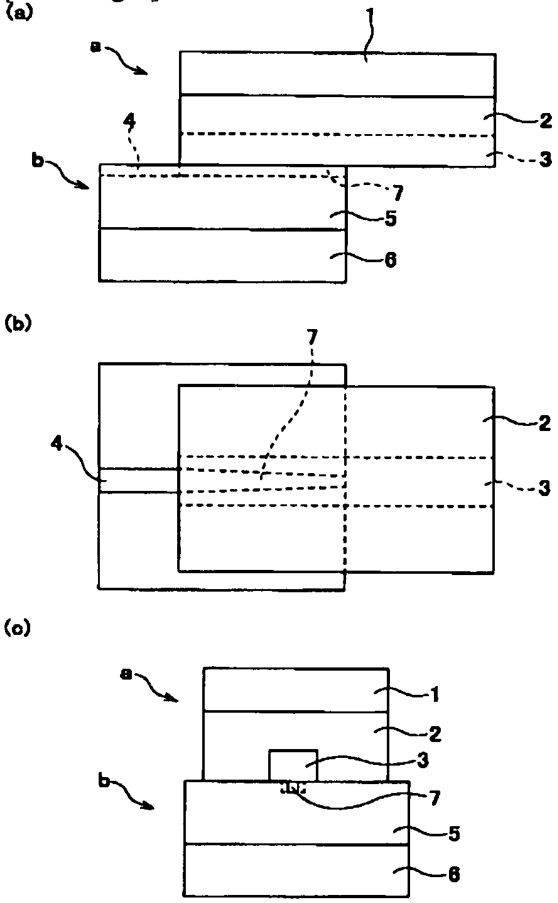
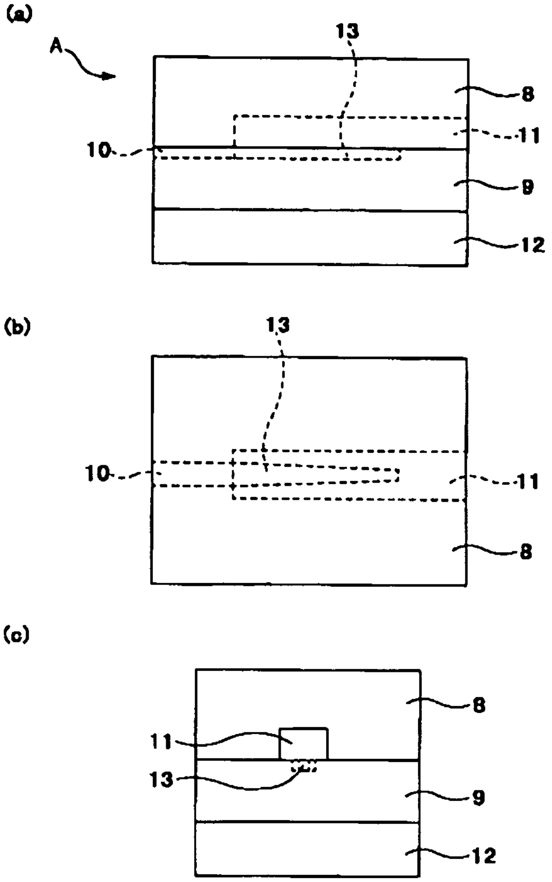
DRAWINGS

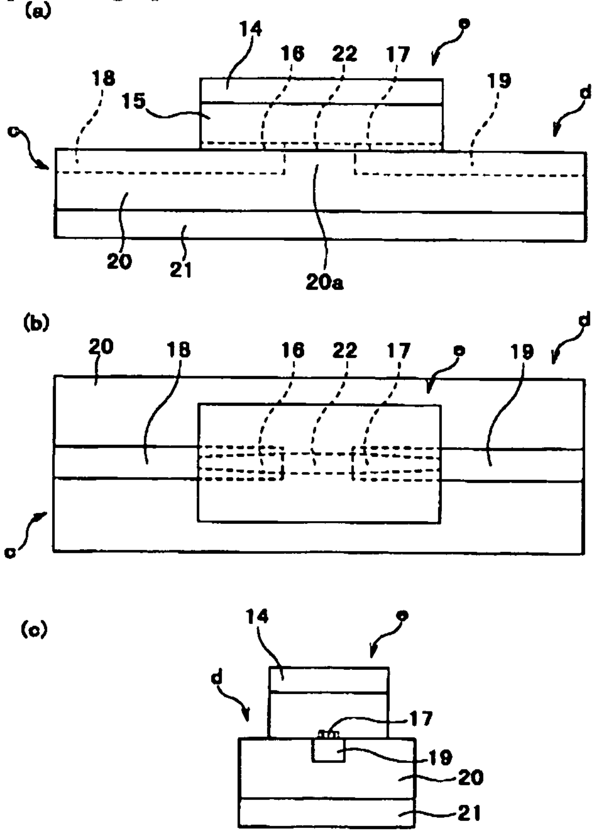
[Drawing 1]



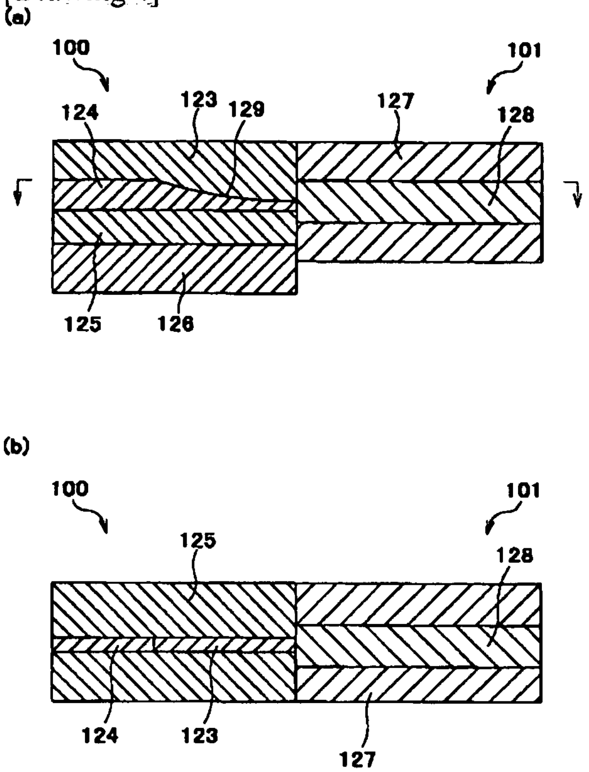
[Drawing 2]


(a)
A
(b)
(c)

[Drawing 3]


(a)
e
d
c
(b)
e
d
c
(c)
e
d

[Drawing 4]



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